small plant requires an experienced electrician as much as a large one. For a plant of 5,000 cubic meters per twenty-four hours the cost of sterilizing the water is from $0.006 to $0.008 per meter, which includes interest on cost of plant (about $40,000), as well as running expenses. For a large plant of 100,000 cubic meters per twenty-four hours the original cost of installation (all parts in duplicate), would amount to about $160,000, but after this outlay the expense of operating would only amount to about $0.0008 to $0.0012 per cubic meter where coal is used to generate power, and where water power could be utilized the expense would be less than half the above. We add to this the interest on the original outlay for the plant and the cost per meter amounts to $0.002 to $0.004.

We thus see that the apparatus requires a considerable outlay of capital at the beginning and must be under the constant control of an electrician, but that in spite of this the proportionate expense is not high for large quantities of water, although always above that of the chloric peroxide process. It is not recommended commercially for small quantities of water, and the apparatus can not conveniently be made portable, as can the first process. However, it presents a means of sterilizing potable water in large quantities that is according to the best authority practically absolute, without the danger, real or imaginary, of adding chemically noxious substances to the water, as is urged by some against the method by chloric peroxide. And the two methods enable us to economically sterilize potable water in those cases where the sources can not be absolutely protected from pollution, and in hospitals, institutions and army camps where special precautions are necessary.

Respectfully, S. B. GRUBBS,
Assistant Surgeon, U. S. M. H. S.

The SURGEON GENERAL,
U. S. Marine-Hospital Service.

[Translation.]

By P. A. Surg. H. D. Geddings, U. S. M. H. S.

THE INDUSTRIAL STERILIZATION OF POTABLE WATERS BY OZONE, BY MEANS OF THE APPARATUS AND PROCESSES OF MESSRS. MARMIER AND ABRAHAM.

LILLE, *February 12, 1900.*

A Report

presented to the Municipality of Lille, by the Scientific Commission appointed by the Municipal Administration, and composed of

Dr. Staes-Braeme, Adjunct to the Mayor, President.

Dr. Roux, Member of the Institute of France, Member of the Academy of Medicine, sub-Director of the Pasteur Institute.

Dr. Buisine, Professor of Industrial Chemistry of the Faculty of Sciences of Lille.

Dr. Calmette, director of the Pasteur Institute of Lille.

Professor of the Faculty of Medicine of Lille.

Dr. Bouriez, Chemical Expert.

(Dr. Calmette, Secretary of the Commission.)

February, 1899.

General considerations.

We know to-day that drinking water is very often the vehicle of infectious diseases, and since this has been proved, hygienists and engineers have diligently sought, availing themselves of the precise methods of experimental science, for means of eliminating, as completely as possible, the pathogenic microbes which are often contained in the water supplies of cities.

Numerous means have already been proposed for arriving at this end. They may be divided into two great categories:

1. Some propose to modify the methods of collecting the water from springs, water courses, or subterranean strata, in order to avoid as much as possible every cause of pollution by microbes coming from the surface of the soil.

2. Others have as their object the separation or destruction of the germs, whose presence is unavoidable in the waters which it is proposed to deliver for use.

Many cities are compelled to drink either water from sources which it is impossible to guard against numerous causes of contamination, or from sources collected superficially in cultivated soil and permeated by surface infiltration.

The city of Lille is found in this latter category. It possesses, in a vast plain which extends along the valley of the Deule, and especially in the neighborhood of the village of Emmerin, a series of springs which break out in the midst of marshes and cultivated lands.

The water-bearing stratum which feeds these springs has its origin in the chalk. Its moderate depth, the location of its points of emergence, and the methods of collection pursued are such that during the entire year the water contains numerous germs, which are derived from the surface of the cultivated soil.

These germs are especially abundant at the time of the great autumn rains. The determination of their species leaves no doubt of the constant danger which their ingestion may lead to. We can prove from time to time each year that numerous cases of typhoid fever exist among the inhabitants of the district of Lille, and it does not appear dubious that the very large infant mortality which is reported by the sanitary office under the heads of "gastro-intestinal affections and athrepsia" ought to be attributed in large part to the defective qualities of the water supply.

Justly impressed with this state of affairs and desirous of protecting the inhabitants as efficaciously as possible from the attacks of epidemic diseases, the municipal administration of Lille is endeavoring on the one hand to largely increase the present output of the springs at Emmerin, which have become insufficient owing to the steady increase of the population, and at the same time to insure the perfect wholesomeness of the water which is distributed.

Almost all methods of purification which have been proposed up to the present time have serious objections when it comes to a question of employing them on a large scale. Filters of porous earth, excellent for the filtration of the water of a household, when they are carefully watched, have too small an output and cost too much to be used for purifying the water of an entire city.

Filtration through beds of sand improves the water, but does not afford absolute safety.

Sterilization by heat is too costly to dream of applying it on a large scale, and among the procedures of chemical purification in the present

state of our knowledge on the subject, the only one which can be shown to be practically efficacious and commendable rests upon the employment of ozone.

We have for a long time known the energetic microbial and oxydizing properties of ozone. The application of this gas to the sterilization of potable waters has been proposed by several savants, notably by Messrs. Ohlmuller, Siemens, and Halske, of Berlin, in 1891; more recently by Messrs. Tindal, Schneller, and Van der Sleen, of Holland.

At the Paris Exposition of Hygiene, opened at the Champ de Mars in 1895, Mr. Tindal exhibited the first practical realization of an apparatus, permitting the efficient treatment of about 2 cubic meters of water per hour. However, the application of the system has not been effected, in a regular way, in any city, and the problem of the practical use of ozone for the purification of large quantities of potable water, remained *in statu quo.*

In 1895 Messrs. Marmier and Abraham undertook the study of this question, and we think that they have made decided advances. In February, 1898, these two scientists asked authority of the municipal administration to establish at the pumping station of the springs at Emmerin, a practical apparatus for the production of ozone, with a view of making a large experiment, which would render it possible to give a verdict upon the practical value of their procedure, and upon the apparatus of their invention.

The administration, thoroughly interested in this experiment, requested us to form a commission to test it, and to give our opinion upon the value of the process.

The commission, composed as previously indicated, met for the first time on December 10, 1898, at the Pasteur Institute of Lille, for the elaboration of a programme for these experiments.

This programme being arranged, the commission was divided into two sections; the one composed of Drs. Roux and Calmette was charged with the bacterial experimentation; the other composed of Messrs. Buisine and Bouriez was charged with the chemical study of the waters of Emmerin before and after the treatment by ozone.

According to the resolutions of the commission regular takings of samples of water, untreated and ozonized, were effected at Emmerin on December 10, 11, and 12, 1898, and on January 17, 24, 27, and 28, 1899, in order to take account of the value of the process in full, continuous, and normal operation.

Description of the apparatus.

The experiment of sterilizing the water was conducted in a small building adjacent to the pumping station of the city of Lille. The apparatus consists of three parts—

1. An apparatus for the production of an electric current.
2. An apparatus for the production of ozone.
3. An apparatus for the sterilization of water.

A.—*Production of the electric current.*

This part of the building contains a steam engine, which presents no peculiarities, and a dynamo. The current produced passes into a high potential transformer, which could give 40,000 volts and upward.

B.—*Production of the ozone.*

The production of the ozone in an uninterrupted fashion is assured by two apparatus, an ozonizer and a sparking machine. Between the poles of this sparker there plays a series of "potential sparks," one of the uses of which is to assure between the poles of the ozonizer, a regular potential. The ozonizer is constructed as follows: An electrode, a glass plate, an interval; a glass plate, an electrode, an interval; a glass plate, an electrode, an interval, etc. The electrodes are metallic, and each one presents two opposite plane surfaces. These surfaces are perfectly flat, and upon each of them is accurately placed the plate of glass. All the electrodes of the even series were joined to one pole of the transformer, all the electrodes of the uneven series to the other pole. Particular precautions have been taken to insure the perfect insulation of these two series of electrodes, for potentials much higher than those ordinarily employed.

In the intervals between the glass plates arises the gaseous body, of a beautiful violet color. Under its action the oxygen of the air is converted into ozone. By means of a special arrangement, air is not drawn from the apparatus until it has traversed a certain distance of ozonizing surface, arranged in advance. All portions of the air, therefore, are subjected to an equal ozonizing influence.

The electrodes are continuously cooled, both sets of electrodes at once. Insulation is, nevertheless, assured, and there is never a short circuit in the apparatus. This is conveniently arranged by passing the column of cooling water through two series of dropping apparatus.

C.—*Sterilization of the water.*

Flowing from the ozonizer the ozone is carried into a large column of masonry. In this column it comes into contact with the water to be sterilized. The sterilization is obtained by a systematic circulation of the ozone and the water. The water escapes at the bottom of the column and flows into the storage reservoirs of the city of Lille. A calibrated weir is put in the course of the exit stream to measure the output.

Bacteriological analysis.

The ozonizing apparatus were in continuous operation, during the day only, from the commencement of July. They were operated day and night during the 10th, 11th, and 12th of December. The normal output of the column was 35 cubic meters of water an hour. Samples of ozonized water intended for bacteriological analysis were collected at Emmerin in sterilized balloon pipettes, and at the same time samples of nontreated water.

On December 10, the untreated water was planted into 5 flasks in a quantity of one-tenth of a cubic centimeter for a preliminary experiment. At the end of from twenty-four to sixty hours all the flasks were altered.

Planted into nutrient gelatin in flat Erlenmeyer flasks, in quantities of from one-tenth to five-hundredths of a cubic centimeter the nontreated water gave after seven days 2,200 germs per cubic centimeter, of which 180 were of the liquefying species.

The ozonized water, after passage through the sterilizing column,

which contained ozone in a concentration of 0.0058 gram to the liter of air, gave the following results:

Bacteriological analysis of ozonized water collected at 10 a. m., December 11.

Output of the column, 35 cubic meters of water per hour. Concentration 0.0058 gram of ozone per liter of air. Temperature of the interior of the ozonizer, 20° C. Temperature of the exterior, 13° C.

Culture medium.	Number flasks planted.	Quantity water planted each flask.	Number germs after 15 days in bouillon or 7 days in gelatin.	Species of germ observed.
		c. c.		
Neutral bouillon	10	0.5	0	
Do	5	1	1	B. subtilis.
Do	1	11	1	Do.
Do	1	12	0	
Do	2	13	0	
Nutrient gelatin	5	1	0	
Do	5	2	0	

Recapitulation.—Two germs of B. subtilis for the total quantity of 74 c. c. of water planted.

On December 11, at 5 p. m., new samples were collected at Emmerin of crude and ozonized water.

The ozonizing apparatus showed a concentration at this time of 0.0065 grams of ozone per liter of air, the output of the column remaining at 35 cubic meters per hour.

The crude water was kept twenty-four hours in the laboratory at a mean temperature of 18° C. Planted at noon of the 12th in gelatin it gave in seven days 3.960 germs per cubic centimeter, of which 340 were liquefying.

Ozonized water taken at 5 p. m., December 11.

Culture medium.	Number flasks planted.	Quantity water planted each flask.	Number germs after 15 days in bouillon or 7 days in gelatin.	Species of germ observed.
		c. c.		
Neutral bouillon	10	1	0	
Do	5	0.5	0	
Do	5	1.3	1	B. subtil.
Do	3	4	0	
Nutrient gelatin	3	1.5	2	1 subtil. 1 mold.

Recapitulation.—Two germs of B. subtilis and 1 mold in a total quantity of 35.5 c. c. of ozonized water planted.

Second series of experiments made January 17 to 24.

On the morning of January 17, 1899, a sample of ozonized water was taken. (Concentration of ozone 0.006 grams per liter of air) the flask was kept in the laboratory for twenty-four hours before planting.

On January 24 a new sample was taken and was kept in the laboratory for thirty-six hours before planting.

The results were as follows:

1.—*Sample of ozonized water analyzed after twenty-four hours.*

Culture medium.	Number flasks planted.	Quantity water planted each flask.	Number germs after fifteen days.
		c. c.	
Neutral bouillon	17	1.2	0

2.—*Ozonized water analyzed after thirty-six hours.*

Culture medium.	Number flasks planted.	Quantity water planted each flask.	Number germs after fifteen days.
		c. c.	
Neutral bouillon	2	7	0
Do	1	13	0
Do	1	15	0

Recapitulation.—Ozonized water, left for twenty-four and thirty-six hours in the laboratory before planting, remained sterile.

On January 27 and 28 the commission made a last series of experiments upon 2 samples taken at intervals of twenty-four hours. The ozonizing apparatus was in continuous operation day and night. The output of the column was 35 cubic meters of water per hour, and the concentration of the ozone was 0.0093 grams of ozone per liter of air.

The crude water taken on the morning of the 27th, at the same time as the samples of ozonized water gave, after six days in gelatin, 1,170 germs per cubic centimeter.

A second sampling of the same water, taken on the morning of the 28th, gave 988 colonies per cubic centimeter.

A balloon pipette of ozonized water, taken on the morning of the 28th and submitted to analysis forty-eight hours afterwards, was thus examined on the morning of the 30th. The results of the analysis of samples of ozonized water taken on the 27th, 28th, and 30th, are given in the three following tables:

Ozonized water taken at Emmerin, 10 a. m., January 30.

Concentration, 0.0093 grams of ozone per liter of air. Output, 35 cubic meters of water per hour. Temperature in interior of ozonizer, 13° C.—Exterior.

Culture medium.	Number flasks planted.	Quantity water planted each flask.	Number germs after 15 days in bouillon or 7 days in gelatin.	Species of germ observed.
		c. c.		
Neutral bouillon	20	1.2	0	
Do	4	3	0	
Do	4	3.5	0	
Do	5	4	0	
Do	2	12	1	B. subtilis.
Do	1	16	1	Do.
Nutrient gelatin	7	3	0	
Do	3	5	0	

Recapitulation.—One hundred and forty-six cubic centimeters of ozonized water, planted into 46 flasks, gave 2 germs of B. subtilis.

Ozonized water collected at Emmerin, 10 a. m., January 28.

Concentration, 0.0095 grams ozone per liter of air. Output of column, 35 cubic meters of water per hour. External temperature, 0° C.

Culture medium.	Number flasks planted.	Quantity water planted each flask.	Number germs after 15 days in bouillon or 7 days in gelatin.	Species of germ observed.
		c. c.		
Neutral bouillon	11	1.4	0	B. subtilis.
Do	15	2.2	1	Do.
Do	2	13	1	Do.
Do	2	9	0	
Do	2	10	0	
Do	1	15	0	
Do	2	18	1	Do.
Do	1	25	1	Do.
Nutrient gelatin	6	2.2	0	

Recapitulation.—One hundred and ninety-two and six-tenths cubic centimeters of ozonized water, planted in 41 flasks, gave 4 germs of B. subtilis.

Ozonized water, collected at Emmerin, 10 a. m., January 28, analyzed January 30, after standing forty-eight hours in the laboratory at a temperature of 18° C.

Culture medium.	Number flasks planted.	Quantity water planted each flask.	Number germs after 15 days in bouillon or 7 days in gelatin.	Species of germ observed.
		c. c.		
Neutral bouillon	6	1	0	
Do	6	2	0	
Do	1	8	0	
Do	3	10	1	B. subtilis.
Do	1	11	0	
Do	1	12	1	Do.
Do	1	13	1	Do.
Do	3	14	1	Do.
Do	2	20	1	Do.

Recapitulation.—One hundred and seventy-five cubic centimeters of ozonize water, kept forty-eight hours in the laboratory gave 5 germs of B. subtilis, which were capable of resuscitation at 36° C.

In the presence of these excellent results, the commission has wished to take account of certain facts which have attracted their attention during the course of the experiments above detailed. It appeared extraordinary, for example, that the ozonized water kept in the laboratory for twelve, twenty-four, thirty-six, or even ninety-six hours, should remain sterile, and should be shown to be relatively poorer in germs than water analyzed a very short time after the taking of these samples.

One might suppose: Either that some germs of the B. subtilis which escaped the action of the ozone during its passage through the column, were destroyed by the very small quantity of ozone which might remain in the liquid during the hours immediately following the taking of the sample; or else that ozonization produces substances in the water which prevent the growth of these germs.

To answer these questions, we mixed with 373 c. c. of ozonized water, taken on January 23, and preserved three days in the laboratory, 68 c. c. of crude water taken on the 26th of the same month. The mixture was planted on the 28th, two days after mixing in the dose of one tenth of a cubic centimeter per flask of nutrient gelatin.

A count of the colonies, made six days after planting and growing at a temperature of 23° C., gave 1,340 germs per cubic centimeter. *Therefore the ozonized water contains no anticeptic substance capable of sterilizing the germs of crude water mixed with it, and thus preventing their growth.*

As we have constantly observed that the ozonized water is proportionately poorer in germs the longer the time after taking that the plantings have been made, we are obliged to conclude that, if the greater portion of the germs contained in the water are destroyed during its passage through the column, almost all of those which escape this phase of the operation succomb in the first few minutes after being led into the reservoirs, where the water coming from the apparatus is stored.

This fact is very interesting to note, because it shows that while the ozonized water may not contain more than traces of ozone, a few minutes after its passage from the apparatus, still the quantity is sufficient to prevent the growth of the B. subtilis which have escaped the sterilization.

Dr. Buisine, professor of industrial chemistry of the faculty of sciences of Lille, and Dr. Bouriez, an expert chemist, were detailed to make comparative analyses of the Emmerin water before and after the

ozone treatment, looking especially to the content of oxygen, organic matter, and nitrates.

It was necessary, in fact, to know if the treatment by ozone had not resulted in increasing to too great proportions the content of the water in nitrates, consequent upon the oxidation of the organic matter contained in the water. The following are the results:

	Crude water.	Ozonized water.
	Gram.	*Gram*
Organic matter (in terms of oxalic acid)	0.014	0.003
Organic matter (in terms of oxygen, process A. Levy)	0.00088	0.00080
Nitric acid (nitrate of potash, process Grandval-Lajoux)	0.034	0.030
Nitrous acid (metaphenylene-Diamine)	0.0005	0.003
Nitrous acid (Resorcin)	0.0005	0.003
Ammonia (process of Nessler)	0.00	0.00
Oxygen dissolved	0.0097	0 0098

To summarize.—The total of the experiments which we have made, bacteriological and chemical, extending from December 10 to February 12, 1899, lead us to conclude that—

1. The process of sterilization of drinking water by ozone, based upon the use of the ozonizing apparatus and sterilizing column of Messrs. Marmier and Abraham, is of incontestable efficiency, and this efficiency is superior to that of all means of sterilization as at present known, which can be applied to the purification of large quantities of water.

2. The very simple arrangement of the apparatus, their strength, the constancy of their output, and the regularity of their action, give all the guarantees which can be expected of a truly practical apparatus.

3. All pathogenic and saprophytic microbes which have been encountered in the waters examined by us are perfectly destroyed by passage through the ozonizing column. Only a few germs of the B. subtilis resist.

We note about one germ of this species for each 15 c.c. of water treated by means of a concentration of ozone equivalent to 6 milligrams per liter of air. With a concentration of 9 milligrams the proportion of germs of B. subtilis, revivifiable by a culture temperature in bouillon, is reduced to 1 germ for each 25 c. c. of water treated.

It is to be noted that the bacillus subtilis (Hay bacillus) is perfectly innocuous to man and animals, and germs of this microbe resist always the greater part of means of destruction, such as heating by steam under pressure at a temperature of 110° C. It is not essential then to require its disappearance in waters intended for drinking, and we consider as amply sufficient the sterilization obtained by a concentration of 5 to 6 milligrams of ozone per liter of air, under the conditions labored under by Messrs. Marmier and Abraham.

4. The ozonizing of the water adds to it nothing of a foreign nature prejudicial to health of the persons who may make use of it. On the contrary, on account of the nonincrease of the content of nitrates, and the considerable diminution of the content of organic matter, waters submitted to the treatment of ozone are less liable to subsequent pollutions, because less alterable in their characteristics. Finally, ozone being nothing more than a peculiar molecular condition of oxygen, the use of this body presents the advantage of energetically oxygenating the water, and rendering it more wholesome and more agreeable for use, and that without removing any of the useful mineral constituents.

5. In so far as concerns the city of Lille our opinion is that it is our duty to recommend to the municipal administration of the city the process of Messrs. Marmier and Abraham, as we have satisfied ourselves of the assured innocuousness and the security acquired by the waters of Emmerin, which are used by all the inhabitants of the province of Lille.

We think that having been given the security afforded by this method of purification the city of Lille would find it advantageous to immediately increase the output of the present springs by simply leading in the waters of the river, or streams of the neighborhood, roughly filtered by a dike of sand, these to be sterilized at the same time with the water of the springs by the ozonizing apparatus.

Whatever may be the depth to which will penetrate the subterranean galleries which are at present projected for a water supply in the neighborhood of Lille, we do not think it can be safely affirmed that the water collected will be safe from surface contamination by reason of the homogeneous nature of the soil alone.

The tunnels pierced into the chalk which supply the city of Rheims afford an example of this. The content of germs and organic matter which is there found varies to a large extent (from 2,000 to 5,000 germs and 12 to 40 milligrams of organic matter per liter), and typhoid fever makes frequent ravages in the population of the city. The collection of deep waters by means of deep borings only gives to hygienists, therefore, a slightly greater security than a surface collection.

We think, therefore, that in order to avoid the propagation of infectious diseases through the instrumentality of drinking water, the latter should be sterilized by an efficient process, such as that the results of which we have set forth in the above report.

By the Commission.

REPORTS FROM THE MEXICAN BORDER.

El Paso, Tex., October 20, 1900—Inspection service.—I have the honor to submit the following summary of work at this station the week ended October 20, 1900: Inspection of Mexican Central Railroad passenger trains, 140 persons; inspection of Rio Grande and Pacific Railroad passenger trains, 37 persons; disinfection of clothing, bedding, etc., of Mexican immigrants, 34 bundles; disinfection of hides imported from Mexico, 412; disinfection of soiled linen imported for laundry, 415. At the time Texas established its quarantine here against bubonic plague the Mexican Government instructed the Ciudad Juarez authorities to enforce a quarantine against San Francisco. Instructions have been received now from the Mexican Government to raise the quarantine.

E. ALEXANDER,
Acting Assistant Surgeon, U. S. M. H. S.

Another death from plague in San Francisco.

The Bureau has received the report of a death from plague in San Francisco which occurred October 14. The diagnosis was confirmed by bacteriologic examination and animal inoculations.